

# 23781

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# VALIDATION OF AIR CONDITIONING SYSTEM DESIGN IN HOTEL X USING CARRIER HOURLY ANALYSIS PROGRAM SOFTWARE 5.01

## Abstract

The design of an Air Conditioning & Ventilation system that is less efficient is made by a Mechanical Electrical & Plumbing (MEP) planning consultant. If the implementation follows the plan, difficulties or irregularities will arise. Almost all hotel and other buildings have an air conditioning & ventilation system design system. Based on this background, the researchers created the title "Validation of Hotel x Air Conditioning System Design Using Carrier Hourly Analysis Program 5.01 Software." The stages are identifying the problem, determining objectives, literature study, location survey, collecting data, calculating the cooling load, then carrying out analysis. The final product of the analysis can produce specifications for air conditioning equipment that suit cooling load requirements.

**Keywords:** Hotel Air Conditioning System Design, CLTD, Carrier Hourly Analysis Program 5.01 Software, Variable Refrigerant Flow (VRF)

## 1. Introduction

Economic growth in Indonesia has shown a figure of above 5% over the last few years. The tourism industry in Indonesia is one area that is very well developed. This increase must be balanced with good hotel accommodation. The air conditioning system is one of the main utilities in a hotel building.

Air flow regulation to create a clean room is generally carried out by using turbulent flow (non-unidirectional airflow), laminar flow (unidirectional airflow) and regulating air pressure inside and outside the room. . ([1] Komarudin, 2010). Hotel buildings must meet thermal comfort factors for their occupants, be safe and efficient from energy and cost aspects. The design of the air conditioning system consists of calculating the hotel's cooling load, selecting the air conditioning system, calculating energy and costs.

Air conditioning & ventilation system design cannot be separated from a building. The more prestigious and comfortable a building is, the higher the planned budget (budget plan). Without good planning this often becomes a problem, if this problem arises at the planning stage it is still much better than if the problem arises during implementation, because it will lead to disassembly work, Air & Ventilation system design that is less efficient is made by MEP planning consultants If the implementation follows the plan, difficulties or irregularities will arise.

Almost all buildings such as offices, hotels, hospitals, apartments, places of worship and shopping

centers have air conditioning & ventilation systems. It is against this background that the researchers created the title "Validation of Hotel X Group Air Conditioning System Design Using Carrier Hourly Analysis Program 5.01 Software"

## 2. Literature review

### 2.1 Hotels & Motels

Hotel and motel accommodation is usually a single guest room with a toilet and bathroom adjacent to the corridor, and flanked by both other guest rooms. The building may be single-story, low-story, or high-rise. Multi-purpose subsidiary facilities range from shops and offices to ballrooms, dining rooms, kitchens, lounges, auditoriums and meeting rooms. Luxury motels can be built with similar facilities. Occasional variations are seen, such as kitchenettes, multi-room suites, and exterior doors to terraces and balconies. Hotel classes range from luxury hotels to economy hotels/motels as outlined in Table 2.1 A hotel can be divided into three main areas: ([2] ASHRAE, 1999)

Table 1 Hotel Classes (1999 ASHRAE Applications Handbook (SI))

Type of Facility	Typical Occupancy, Persons per Room	Characteristics
Deluxe hotel	1.2	Large rooms, suites, specialty restaurants
Luxury/first class, full-service hotel	1.2 to 1.3	Large rooms, large public areas, business center, pool and health club, several restaurants
Mid-scale, full-service hotel	1.2 to 1.3	Large public areas, business center, several

1 Type of Facility	Typical Occupancy, Persons per Room	Characteristics
		2 restaurants
Convention hotels	1.4 to 1.6	Large number of rooms, very large public areas, extensive special areas, rapid shifting of peak loads
Limited-service hotel	1.1	Limited public areas, few restaurants, may have no laundry
Upscale, all-suites hotel	2.0	Rooms are two construction bays, in-room pantries, limited public areas, few restaurants
Economy, all-suites hotel	2.0 to 2.2	Smaller suites, limited public areas and restaurants
Resort hotels	1.9 to 2.4	Extensive public areas, numerous special and sports areas, several restaurants
Conference center	1.3 to 1.4	Numerous special meeting spaces, limited dining options
Casino hotels	1.5 to 1.6	Larger rooms, large gaming spaces, extensive entertainment facilities, numerous restaurants
Economy hotel/motel	1.6 to 1.8	No public areas, little or no dining, usually no laundry

Generally, the air temperature in hotels that is in accordance with the Design Criteria according to the 1999 ASHRAE Applications Handbook (SI) is in table 2 & 3:

Table 2 Hotel Design Criteria (1999 ASHRAE Applications Handbook (SI))

Category	Inside Design Conditions				Ventilation <sup>6</sup>	Exhaust <sup>6*</sup>	Filter Efficiency <sup>7</sup>	RC Level
	Winter Temperature	Winter Relative Humidity <sup>8</sup>	Summer Temperature	Summer Relative Humidity				
Guest rooms	23 to 24°C	30 to 35%	23 to 26°C	50 to 60%	15 to 30 L/s per room	10 to 25 L/s per room	10 to 25%	25
Lobbies	20 to 23°C	30 to 35%	23 to 26°C	40 to 60%	8 L/s per person	-	35% or better	45
Conference/Meeting rooms	20 to 23°C	30 to 35%	23 to 26°C	40 to 60%	10 L/s per person	-	35% or better	35
Assembly rooms	20 to 23°C	30 to 35%	23 to 26°C	40 to 60%	8 L/s per person	-	35% or better	25

<sup>1</sup>This table should not be used as the only source for design criteria. The data contained here can be determined from ASHRAE handbooks, standards, and governing local codes. <sup>2</sup>Design criteria for stores, restaurants, and swimming pools are in Chapters 2, 3, and 4, respectively.

<sup>3</sup>As per ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality.

<sup>4</sup>Air exhaust from hall and other areas.

<sup>5</sup>As per ASHRAE Standard 52.1, Methods of Testing and Reporting Procedures for Testing Air-Cleaning Devices Used in Ventilation Systems for Removing Particulate Matter.

<sup>6</sup>Minimum recommended humidity.

The temperature data used in this research uses a Summer design condition in the geust rooms area with a temperature of 23°C ~ 26°C & RH 50% ~ 60%.

Table 3 Design Criteria for Hotels (1999 ASHRAE Applications Handbook (SI))

Category	Inside Design Conditions	Comments
Kitchen (general) <sup>b</sup>	28°C	Provide spot cooling Kitchen
Kitchen (general) <sup>b</sup>	24°C	Provide spot cooling Kitchen
Kitchen (chef's office) <sup>b</sup>	23 to 26°C 50 to 60% rh (summer) 30 to 35% rh (winter)	Fully air conditioned
Housekeeper's office	23 to 26°C 50 to 60% rh (summer) 30 to 35% rh (winter)	Fully air conditioned
Telephone equipment room	Per equipment criteria	Stand-alone air conditioner; air conditioned all year ment room
Wine storage	Per food and beverage manager criteria	air conditioned all year
Laundry		Spot cooling as required at workstations

<sup>a</sup>Governing local codes must be followed for design of the HVAC.

<sup>b</sup>Consult Chapter 30 for details on kitchen ventilation.

Recommendations for the location of the AC unit that will be used in this research refer to the Design Criteria according to the 1999 ASHRAE Applications Handbook (SI) for hotel rooms above the ceiling (Hanging) as shown in Figure 1

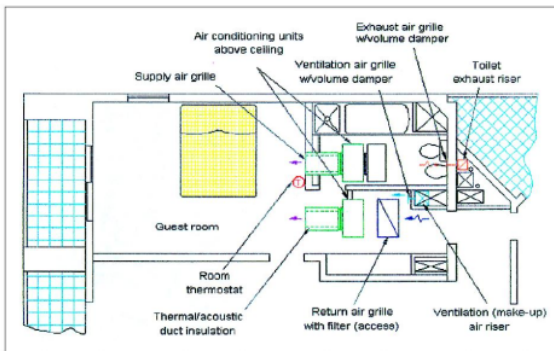


Figure 1 Location of Hotel Room AC Units (1999 ASHRAE Applications Handbook (SI))

### Manual Cooling Load Calculation (CLTD)

Cooling load is the load that must be borne by cooling equipment due to the presence of heat sources both from inside the room and outside the room that is to be conditioned. At the planning stage, the correct cooling load calculation must be carried out because the results of the correct cooling load calculation will be the basis for selecting the type and capacity of cooling equipment. This complex procedure takes into account both thermal mass and occupancy time, and requires consideration of which hours may be most critical. therefore, the more precise Cooling Load Temperature Differences (CLTD) cooling load calculation method (based on ASHARE Handbook of

Fundamentals, 1981) can only be used if the following information is available ([8] Benjami Stein, 1986).

- 1) Characteristics of building type: material, size, outer surface color, and shape.
- 2) The location and orientation of the building, as well as the extent of external shading of the building by trees or adjacent structures.
- 3) Outdoor design conditions.
- 4) Indoor design conditions: DB, WB, and ventilation level.
- 5) Lighting schedules, occupancy, equipment, and other processes that contribute to internal heat gain.
- 6) Bind days and months to calculate cooling loads. determining this factor may require a quick initial comparison between the relative impacts of solar gain through roofs and glazing at various orientations.
- 7) Zoning requirements.

### External Load

External loads are loads originating from outside the room which are conditioned or which are directly related to the environment. The external cooling load consists of the heat load generated by the roof, walls, glass and floor. The loads on the roof, walls, glass and floor can be obtained using the following equations.

#### a) Load Through the Roof

$$q = U \times A \times CLTD_{corr} \quad ([9] \text{ ASHARAE, 1980})$$

Where :

- Q = Roof cooling load, (Btu/hr)
- U = Heat transfer coefficient on the roof, (Btu/hr.ft<sup>2</sup>.°F)
- A = Roof area, (ft<sup>2</sup>)

CLTD<sub>corr</sub> = The temperature difference between the design and the existing loads. To find the CLTD<sub>corr</sub> of the roof, you can use the following equation:

$$CLTD_{corr} = [(CLTD + LM) \times K + ((78 - Tr) + (To - 85))] \times f$$

Where:

- CLTD = Cooling load temperature different
- L.M = Latitude and Month
- K = Color usage factor, (1.0 if dark colored)
- To = Outside air temperature, (oF)
- Tr = Design temperature, (oF)

f = Factor for channels above the ceiling (0.75 if positive ventilation)

#### b) Load Through Walls

$$q = U \times A \times CLTD_{corr}$$

Where :

- Q = Wall cooling load, (Btu/hr)
- U = Wall heat transfer coefficient, (Btu/hr.ft<sup>2</sup>.°F)
- A = Wall surface area exposed to solar radiation, (ft<sup>2</sup>)
- CLTD<sub>corr</sub> = The temperature difference between the design and the existing loads. To find the CLTD<sub>corr</sub> of the wall, you can use the following equation:

$$CLTD_{corr} = (CLTD + LM) \times K + (78 - Tr) + (To - 85)$$

Where:

- CLTD = Cooling load temperature different
- L.M = Latitude and Month
- K = Factor use of color, (0.65 if permanently light colored)
- To = Outside air temperature, (oF)
- Tr = Design temperature, (oF)

#### c) Load Through Conducting Glass

$$q = U \times A \times CLTD$$

Where :

- q = The amount of heat received by the glass, (Btu/hr)
- U = Heat transfer coefficient for glass, (Btu/hr.ft<sup>2</sup>.°F)
- A = Glass surface area, (ft<sup>2</sup>)
- CLTD = Cooling Load Temperature Difference

#### d) Radiation Load through Glass

$$q = A \times SC \times SHGF_{max} \times CLF$$

Where :

- q = Glass cooling load via radiation, (Btu/hr)
- A = Glass surface area, (ft<sup>2</sup>)
- S.C = Shading Coefficient for glass types
- SHGF = Solar Heat Gain Factor
- CLF = Cooling Load Factor

#### e) Loads through Partitions, Ceilings and Floors

$$q = U \times A \times \Delta T$$

Where :

- q = Partition, ceiling and floor cooling loads, (Btu/hr)
- U = Heat transfer coefficient for walls, (Btu/hr.ft<sup>2</sup>.°F)

A = Areawall surface, (ft<sup>2</sup>)  
 $\Delta T = (T_o - T_r)$  = The temperature difference between the design (Tr) and the adjacent space (To), (°F)

### Internal Load

#### a) Lighting Load (Lamps)

$$q = 3.41 \times q_i \times F_u \times F_s \times CLF$$

Where :

q = Loadlighting cooling, (Btu/hr)  
 $q_i$  = Total input powerlamp, (Btu/hr)  
 $F_u$  = The factor of the lights being on, ( $F_u = 1$  because all lights are on)  
 $F_s$  = Ballast factor  
 $CLF$  = Cooling Load Factor

#### b) Occupant Expenses

The load caused by human activities can be calculated using the following equation:

$$q_s = n \times \text{Sens. H.G} \times CLF$$

$$q_l = n \times \text{Lat. H.G}$$

Where :

$q_s$  = Sensible load, (Btu/hr)  
 $q_l$  = Latent load, (Btu/hr)  
 $n$  = Number of people  
 $\text{Sens. H.G}$  = Sensible Heat Gain  
 $\text{Lat. H.G}$  = Latent Heat Gain  
 $CLF$  = Cooling Load Factor

#### c) Equipment Load

$$q_s = C_s \times q_r \times CLF$$

$$q_l = C_l \times q_r$$

Where :

$q_s$  = Sensible load, (Btu/hr)  
 $q_l$  = Latent load, (Btu/hr)  
 $C_s/C_l$  = Coefficient for equipment  
 $q_r$  = Total equipment input power, (Btu/hr)  
 $CLF$  = Cooling Load Factor

#### d) Heat Load from Ventilation

$$q_s = 1.1 \times Q \times \Delta T$$

$$q_l = 4840 \times Q \times \Delta W$$

Where :

$q_s$  = Ventilation air sensible heat transfer rate, (Btu/hr)  
 $q_l$  = Ventilation air latent heat transfer rate, (Btu/hr)  
 $Q$  = Volumeair flow, (CFM)  
 $\Delta T$  = The difference between the outside air temperature and the design temperature, (°F)  
 $\Delta W$  = The difference in humidity ratio between outside air and inside air Room

#### e) Heat Load from Infiltration

$$q_s = 1.1 \times CFM \times \Delta T$$

$$q_l = 4840 \times CFM \times \Delta W$$

Where :

$q_s$  = Sensible heat transfer rate of infiltrated air, (Btu/hr)  
 $q_l$  = Latent heat transfer rate of infiltrated air, (Btu/hr)  
 $\Delta T$  = Difference between outside air temperature and design temperature, (°F)  
 $\Delta W$  = Difference in humidity ratio between outdoor air and indoor air

$$CFM = ACH \times \text{Volume (ft}^3) / 60$$

$CFM$  = Air Conditioning Principles and Systems, Edward G. Pita, p. 156

### 2.3 Hourly Analysis Program 5.01 (HAP 5.01) Carrier Cooling Load Calculation

The first step is to open the Hourly Analysis Program (HAP 5.01)

#### Weather Data (Weather)

Design weather data is used to estimate the magnitude of cooling and heating loads in accordance with industry standard practices. This data consists of 24 hours of temperature and air humidity which represents the sunlight conditions each month.

#### 1. Parameter Design

Design parameters contain information about the geographic location of the building, summer and winter design conditions, local soil conditions, local time specifications and month ranges to be used in the cooling design calculations.

#### 2. Temperature Design

The design temperature contains information about the design cooling temperature and humidity profile per day. This feature on the label can be used to view and modify the design.

#### 3. Solar Design

The solar design incorporates peak heat loads for the cooling design. This feature on the label can be used to view data on the amount of heat load during peak conditions and adjust the design profile.

#### 4. Simulation

The simulation contains information about the simulated weather data used in the project. Apart from that, it is also used to determine the energy simulation operation calendar.

### 5. Spaces (Space)

Buildings are divided into units referred to as spaces when it comes to analyzing their thermal behavior. In the simplest sense, space is a room consisting of a number of elements such as walls, roofs, windows, and internal heat loads that influence heat transfer into and out of the space. Apart from that, the space is also provided with one or more air distribution terminals.

### 6. Air System (System)

The system is used to determine the type of airside arrangement to use. There are two choices of methods for controlling the air side, namely setting a constant air volume rate (CAV) and setting a variable air volume rate (Variable Air Volume/VAV). Apart from that, the system is used to determine the air ventilation, type of fan supply, AC unit type equipment and temperature settings on the thermostat.

### 2.4 Research methods

This research method aims to understand more about the complexity of air conditioning systems, including the stages, regulations, procedures and infrastructure involved in designing air conditioning systems.

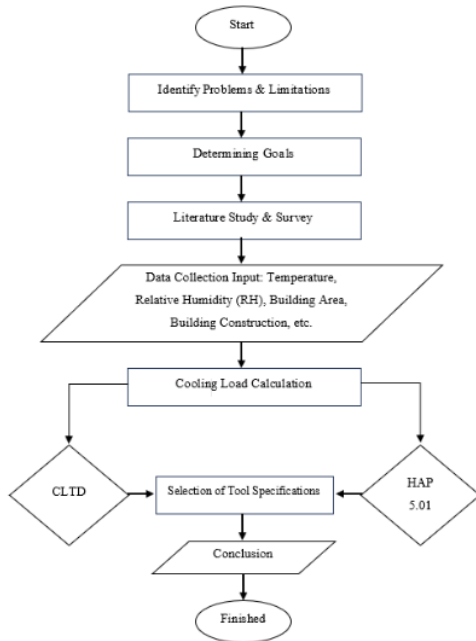


Figure 2 Research flow diagram

## 3. Results and Discussion

### 3.1 Hotel Room Specification Data

Table 4 Number of Hotel Rooms

Room	Amount	Room Size		Total Room Area	
		Foot <sup>2</sup> area	Area m <sup>2</sup>	Foot <sup>2</sup> area	Area m <sup>2</sup>
Standard Type Room	90	242.84	22.56	21,855.6	2,030.4
Mid Type Room Internal	8	265.98	24.71	21,27.84	197.68
Mid Type Room External	8	270.82	25.16	21,66.56	201.28
Suite Type Living Room	3	339.70	31.56	1,019.1	94.68
Suite Type Bedroom	3	268.34	24.93	805.02	74.79
Owner's Suite Living Room	1	339.70	31.56	339.7	31.56
Owner's Suite Bedroom	1	268.34	24.93	268.34	24.93
<b>Total</b>	<b>114</b>	<b>1995,72</b>	<b>185,41</b>	<b>28,582,16</b>	<b>2,655,32</b>

### 3.2 CLTD Sensible Load and Latent Load Calculation Results

The following are the results of calculating sensible load, latent load & total load for each hotel room using CLTD calculations.

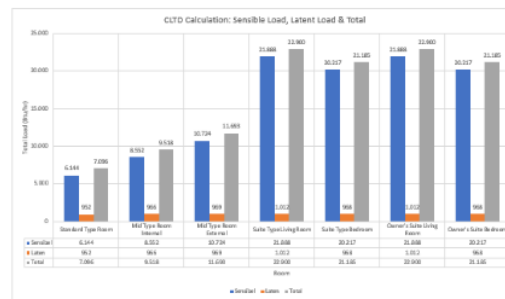


Figure 3 Sensible, Latent & Total CLTD Burden

From the graph of the CLTD calculation results above, it can be seen that the highest sensible load is in the Suite Type Living Room & Suite Type Living & Owner's Suite Type Living hotel rooms among the sensible loads in other rooms, namely 21,888 Btu/hr, this is due to the influence of the wall area, glass area, ceiling area, number of equipment, lighting and occupants in each room are different. Meanwhile, the highest latent load was found in the Suite Type Living & Owner's Suite Type Living hotel rooms, namely 1,012 Btu/hr, this was due to the number of equipment, lighting and occupants in each room being different.

Table 5 Total CLTD AC Capacity

Room	Amount	CLTD capacity		
		Sensible	Latent	Total BTU/H
Standard Type Room	90	6,144	952	638,602
Mid Type Room Internal	8	8,552	966	76,146
Mid Type Room External	8	10,724	969	93,544
Suite Type Living Room	3	21,888	1,012	68,700
Suite Type Bedroom	3	20,217	968	63,555
Owner's Suite Living Room	1	21,888	1,012	22,900
Owner's Suite Bedroom	1	20,217	968	21,185
<b>Total</b>	<b>114</b>	<b>109,630</b>	<b>6,847</b>	<b>984,631</b>

### 3.3 HAP Software Cooling Load Calculation

The following is a comparison of CLTD capacity calculations with Carrier HAP 5.01 software for each hotel room, where there are differences in theoretical calculations and Carrier HAP 5.01 software as follows:

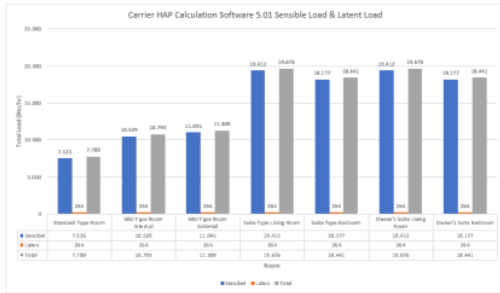


Figure 4 Sensible, Latent & Total HAP 5.01

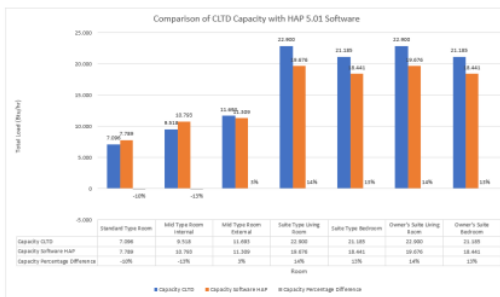


Figure 5 Comparison of CLTD & Total Load HAP 5.01

From Figure 5, the comparison results of CLTD theory calculations with the Carrier HAP 5.01 Software above, it can be seen that the calculation between CLTD and the Carrier HAP 5.01 Software for Standard type rooms is a difference of - 10% greater than the HAP 5.01 calculation, the orange line is above the blue line, for Mid Type Internal Rooms. difference - 13%, Mid Type Room External CLTD blue line rooms are 3% higher than the HAP 5.01 calculation, Suite Type Living Room CLTD blue line rooms are 14% higher, Suite Type Bedroom CLTD blue line rooms are 13% higher, Owner's Suite rooms The CLTD blue line Living Room is 14% higher, the CLTD blue line Owner's Suite Bedroom is 13% higher.

### 4. Conclusion

Based on the analysis and calculations that have been carried out at Hotel X, the conclusions are as follows:

- Based on the CLTD calculation, it is:
  - Total Sensible Cooling Load :109,630 BTU/H
  - Total Latent Cooling Load: 6,847 BTU/H
  - Total Sensible & Latent Cooling Load: 984,631 BTU/H
- Based on the calculations of HAP 5.01 Software are:
  - Total Sensible Cooling Load :104,277 BTU/H
  - Total Latent Cooling Load: 1,848 BTU/H
  - Total Sensible & Latent Cooling Load: 1,030,294 BTU/H
- Using CLTD calculations can take longer to calculate due to the need to manually enter cardinal correction factors and time inefficiency in data input.
- The use of CLTD calculations is more detailed due to the theory of calculating latent internal loads on equipment & ventilation loads.
- Using HAP 5.01 software can provide faster calculations and time efficiency in data input
- The use of HAP 5.01 Software calculations is not more detailed because there is no theory for calculating latent internal loads on equipment & ventilation loads.
- Thank You**

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